

DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 135

CAUSTIC MAGNESIA CEMENT

OCTOBER 16, 1922



PRICE, 5 CENTS

Sold only by the Superintendent of Documents, Government Printing Office,
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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CAUSTIC MAGNESIA CEMENT.

(Also called magnesite cement, magnesia cement, magnesium oxychloride cement, Sorel cement, plastic magnesia cement, and light calcined magnesia cement.)

ABSTRACT.

A brief summary of the discovery, early history, and later application of the reaction of caustic magnesia with solutions of magnesium chloride. The result of this reaction produces a quick-hardening cement used in the stucco, flooring, and ship decking trade. Short descriptions are given of the ore used, of methods of calcining the ore, also suggested formulas for several types of products, the general qualities of these, and the lines along which specifications for the cement are being developed.

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I. INTRODUCTION.

Although the cementing material produced by the reaction of magnesite calcined at a low temperature with a solution of magnesium chloride has been known for somewhat more than half a century, its commercial utilization has been decidedly hampered by the secrecy maintained by those who have made a commercial success of its use. The products of caustic magnesia cement are before the public under numerous proprietary names, frequently with no indication as to the essential ingredients. This especially accounts for the general lack of familiarity by the public with the material and the narrowness of the field of application in the building industry.

Within recent years the public has begun to realize its value and its limitations, and also the general similarity between the variously named products; consequently there has been an increase in its use. However, a greater general knowledge of the material

and the industry is needed to further its proper growth. This is the intent of this circular—the furnishing of a convenient source of general information on the subject of caustic magnesia cement, and not an attempt to add to the information already collected by those in close touch with the industry.

The title of the paper and the use of the term “caustic magnesia” has been adopted after considerable thought. The more commonly used name for the cement is “plastic magnesite.” But this is obviously a misnomer, as it is not magnesite but magnesia. The former is the mineralogical name of the carbonate of magnesium and after calcination its residue is oxide of magnesium or magnesia. If the mineral is calcined at a low temperature, the resulting oxide is both plastic and caustic; that is, when mixed with water it produces a sticky mass which is strongly alkaline. In view of the inability to properly define the term “plastic” when applied to such products, it was deemed more advisable to use the term “caustic,” which is a term understood by the general public and the trade and serves to distinguish that oxide of magnesium suitable for cement from that calcined at a higher temperature which reacts with water but very slowly to cause the solution to become caustic or alkaline. It might have been desirable to have used the name “Sorel cement” as an honor to the one who first noted the cementing value of the result of the reaction of the oxide and a solution of the chloride of magnesium. But a name which will indicate the nature or composition of a product should be conceded to be the most desirable.

II. EARLY HISTORY AND CHEMISTRY OF CAUSTIC MAGNESIA CEMENT.

Possibly the first reference to the use of magnesia as a cement is that contained in the English translation by Capt. J. T. Smith of Vicat's “A Practical and Scientific Treatise on Calcareous Mortars and Cements.” Vicat, whose name has been connected with the earliest investigations of cement and is still familiar to cement testers through the “Vicat needle,” published his treatise in 1818. In the translation published by Captain Smith in 1837 the translator has added an appendix to the discussion dealing with the effect of magnesia in calcareous cements, part of which is as follows:

Extensive beds of the native carbonate of magnesia have been recently discovered in the south of India, near Salem and Trichinopoly, in the Madras Presidency, and the supply is so abundant that measures have been already taken for turning this

valuable material to account as a cement, for which purpose the experiments of Colonel Pasley have shown it to be admirably adapted. Some varieties of the mineral are so hard, previous to calcination, as to strike fire with steel; others are of a softer description. The constituents of a specimen analyzed by my friend Dr. Malcolmson, of the Madras medical service, to whose kindness I am indebted for the following particulars, are, in 100 grains, magnesia $47\frac{1}{2}$, carbonic acid $51\frac{1}{2}$, water one-half, and silica one-half, the proportion of the last ingredient varying in the different samples within very narrow limits. After calcination the magnesia does not slake like lime, but when powdered and made into a paste a sensible heat is extricated; it is capable of hardening under water, though it is preferable to allow it to dry for 12 hours or more previous to immersion. In time it acquires a firm consistency, and even as a common stucco it has been described as of "extreme hardness." An admixture of not more than one and a half times its bulk of clean sand is found to improve its qualities for general purposes, at the same time that it diminishes its cost, but the proportion of such alloy must, of course, be regulated by the use for which the mixture is intended. As a stucco it is considered the most beautiful of all cements, and that even at Madras, where the chunam,¹ so long celebrated, is made in the greatest perfection.

It is not known whether magnesia is still used in India in this manner or not, though India still continues to be an important source of the cement. At the present time in other countries the caustic magnesia is not mixed or gaged with water but with a solution of chloride of magnesium.

In 1867 Stanislaus Sorel,² a French civil engineer, announced the discovery of magnesium oxychloride cement. A few years previous to this he had discovered zinc oxychloride cement, which has been used since for fillings in teeth. The former was produced by calcining magnesite and wetting the product with a solution of magnesium chloride (20 to 30° B.) This mixture set to a hard dense mass, the stronger solutions giving the harder cements. With suitable admixtures, a product was formed having the hardness and appearance of marble. He stated that the magnesium chloride could be replaced by a number of other salts, but that the chloride produced the hardest cement.

Though Sorel did no work to determine the chemical constitution of this cement, he suggested that it was a mixture of oxychlorides. The first account of an investigation of the constitution was published in 1870 by Bender,³ who found the formula of cement which had been stored in air for six months to be $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 17\text{H}_2\text{O}$. After treating this with cold water the compound $\text{MgCl}_2 \cdot 9\text{MgO} \cdot 24\text{H}_2\text{O}$ remained. The original com-

¹ A lime stucco, to the top coat of which is added white of egg, butter fat, milk curd, and soapstone. It is polished by rubbing with soapstone blocks. The first coat is composed of lime, small shells, or sand, and gaged with brown sugar water; the second coat is the same but, sugar is not used; top coat is applied thin before second coat has set.

² C. R., 65, p. 102.

³ Ann. d. Chemie, 159, p. 341.

pound treated with boiling water gave the formula $2\text{MgO} \cdot 3\text{H}_2\text{O}$. Following this publication, a great variety of formulas were suggested by different investigators as results of as many different methods employed. Some of these are outlined very briefly below:

Krause and Nuhman,⁴ respectively, separated the compounds $\text{Mg}(\text{OH})\text{Cl} \cdot 4\text{Mg}(\text{OH})_2 \cdot 5\text{H}_2\text{O}$ and $\text{Mg}(\text{OH})\text{Cl} \cdot 5\text{Mg}(\text{OH})_2$.

Andre⁵ boiled 20 g. of calcined magnesia in a solution of 400 g. of magnesium chloride 500 g. of water, filtered and cooled. The filtrate deposited needles of $\text{MgCl}_2 \cdot \text{MgO} \cdot 16\text{H}_2\text{O}$. This salt is decomposed by water and alcohol.

The crystalline deposit frequently formed in a magnesia mixture was found by Davis to be $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 13\text{H}_2\text{O}$. On washing the crystals with a large quantity of water they became hydrated magnesium oxide.

Robinson and Waggeman found the normal composition of this oxychloride to be $3\text{MgO} \cdot \text{MgCl}_2 \cdot 10\text{H}_2\text{O}$. The oxychlorides prepared by Andre, Davis, and Krause were shown by Fahrman⁶ to be identical and of the composition $3\text{MgO} \cdot \text{MgCl}_2 \cdot 7\text{H}_2\text{O}$. By electrolysis of a magnesium chloride solution Hoff⁷ collected about the cathode a white solid of the composition $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 14\text{H}_2\text{O}$. Kallenuer⁸ considered that the cement was not an oxychloride, but a solid solution of magnesium chloride in magnesium hydroxide from the fact that the magnesium chloride can be entirely washed out, leaving a hard residue, and from thermochemical data (not published) which he had obtained.

In connection with this, it may be interesting to examine a recent analysis of a magnesite stucco which was placed in an experimental panel at this bureau during 1916. This analysis was as follows:

	Per cent.
"S ₂ and ₃ " (insoluble in HCl).....	61.77
R ₂ O ₃	.17
CaO.....	.83
MgCl ₂	3.38
MgO.....	16.50
CO ₂	3.84
Loss at 110° C.....	4.51
Combined water (by difference).....	9.00

⁴ Chemischer Zeitung, 25, p. 96.

⁵ C. R., 94, p. 444.

⁶ Munchen, Tonindustrie Zeitung, 35, pp. 265-266.

⁷ Chemischer Zeitung, 33, pp. 693-694.

⁸ Chemischer Zeitung, 33, p. 871.

The percentage composition of the cementing portion is as follows:

	Per cent.
R ₂ O ₃	0.44
CaO.....	2.28
MgCl ₂	8.84
MgO.....	43.15
CO ₂	10.05
Loss at 110° C.....	11.79
Combined H ₂ O (by difference).....	23.45

Although little is known about the original material, as it now occurs in the panel, it appears from computation and comparison with other stucco mixtures that the MgCl₂ content in the weathered stucco is lower and the CO₂ content is higher than originally. This indicates that MgCl₂ has been leached out and that CO₂ from the atmosphere has combined with a magnesium compound. It is still a question as to what effect this gradual change will have upon the structure of the stucco, which at the present time is generally most satisfactory.

III. MAGNESITE.

1. OCCURRENCE.

Practically all caustic magnesia used in other than the heat insulating trade is made by calcining magnesite. This mineral is found in many parts of the world, but many of the deposits are comparatively small. Probably the most notable deposits abroad are those in Austria, Czechoslovakia, Greece, and India. Very large deposits occur in New South Wales, New Caledonia, and Portuguese West Africa. Large quantities have been found on the island of Margarita near Venezuela and on the island of Santa Margarita in Magdalena Bay. Some large deposits of a crystalline high-lime magnesite occur in eastern Canada, while large deposits of amorphous magnesite and hydromagnesite have been reported in British Columbia.

In this country, magnesite has been found in Maryland, New Jersey, Massachusetts, New York, North Carolina, Pennsylvania, Nevada, California, and Washington. The only deposits of much commercial value at present are those in California and Washington. That in Nevada is undeveloped and the magnesite is not high grade.

2. NATURE.

The mineral magnesite is a naturally occurring form of magnesium carbonate, MgCO₃. It appears in two modifications.

AMORPHOUS.—This form is hard, compact, often concretionary, and probably is a hardened precipitate. The fracture is conchoidal, having the appearance and color of unglazed porcelain. Amorphous magnesite is generally the result of alteration of serpentine or similar high magnesian rocks and is commonly found in fissures or veins associated with the rocks from which it was derived. The deposits of Greece and California are examples of this class.

CRYSTALLINE.—The chief crystalline magnesite deposits are in Austria, Czechoslovakia, Canada, and the State of Washington. This modification probably was a replacement of lenses of dolomite produced by magnesian solutions. It occurs in masses along with limestone, dolomite, or associated sediments which have been metamorphosed. The structure is coarsely crystalline, and the color is white, pink, red, gray, or black.

3. IMPURITIES.

Magnesite is often very pure, containing only small amounts of silica, alumina, iron oxide, and lime. Lower grades contain admixtures of lime, clay, oxides of iron, serpentine, or some form of free silica. Manganese is found in some deposits in sufficient quantity to affect the color of the calcined magnesite.

IV. CAUSTIC MAGNESIA.

Two types of kilns are in common use for calcining magnesite, the vertical stack kiln and the rotary kiln. The former type may be fired with wood, coal, coke, oil, or gas; whereas the rotary kiln is restricted to oil, gas, or powdered coal. The calcining operation consists of heating the sized magnesite until nearly all the carbon dioxide has been driven off, and, in certain cases, of further heating. Depending on the properties desired in the resulting magnesium oxide, a calcined magnesite falls into one of two general classes, namely, dead burnt magnesite and caustic magnesia. The properties of these two classes are very different and, furthermore, the properties often vary greatly within each class.

Dead burnt magnesite is produced by heating the magnesite sufficiently to change the amorphous magnesium oxide, which is first formed, into the dense crystalline state as found in nature and known as periclase. The temperature required to form periclase is lowered by the presence of iron, and therefore in preparing dead burnt magnesite either a magnesite containing about the

desired amount of iron is selected or iron oxide is added to a magnesite containing less of this impurity. Dead burnt magnesite is an excellent refractory material under certain conditions and is used extensively in lining furnaces for making basic open-hearth steel, in copper converters, reverberatories, and in furnaces for refining lead. It is not plastic and reacts only very slowly with water or magnesium chloride.

On the other hand, if magnesite is heated only sufficiently to drive off the greater part of the carbon dioxide, the product will be amorphous, of relatively low specific gravity, and if treated with water or a number of salt solutions becomes plastic and sets rapidly into a hard mass. If the temperature of calcination is increased, the product will be denser and less active chemically. Pure magnesium carbonate will lose all its carbon dioxide at approximately $510^{\circ}\text{C}.$ ⁹ Commercially, the temperature employed in calcining magnesite for use as a cement is much higher than this and probably varies from 700 to $1,200^{\circ}\text{C}.$ The very low calcined product, if recently calcined, is too quick setting, without a retarder, for use as a structural cement.

The other extreme, represented by a highly calcined magnesite, will not be sufficiently active and will give too slow set. Properties other than the rate of setting are affected by the manner in which the magnesia has been calcined. Therefore the manufacturer should calcine the magnesite to a degree which will result in a product having satisfactory properties. It is misleading to say that a satisfactory product may be obtained by burning at some fixed temperature, as the temperature required in the kiln will vary with the nature of the magnesite, impurities, duration of the calcining operation, size of particles, and surface of magnesite exposed to the sources of heat. To determine the most efficient conditions which will give the desired product is then a problem for the individual plant.

If exposed to the atmosphere, plastic magnesia will take up water and carbon dioxide at a rate depending upon the conditions of exposure and the degree of calcination. This absorption may be very marked in the case of a lightly calcined magnesia, and the behavior of the cement will be affected greatly.

⁹ U. S. Geological Survey Bulletin No. 355, p. 10.

V. USES OF CAUSTIC MAGNESIA CEMENT.**1. FLOORING.**

Probably the earliest use made of this cement was in imitation stone or building blocks, where it proved unsuccessful, as the blocks were not durable under exposure to the weather. However, it was soon found that if mixed with various ingredients the material had desirable properties for interior construction, particularly as flooring. It was used extensively in this way in France and Germany before the trade was introduced into this country.

The properties of this so-called composition flooring largely depend upon the ingredients which are mixed with the cement. The floors may vary from a hard, dense type to one comparatively soft and resilient. Many different materials have been used in flooring mixtures to bring out certain of these qualities, as sand, ground silica, sawdust, and other fibrous vegetable matter, asbestos, leather scrap, ground cork, talc, clay, kieselguhr, and pigments. Many different formulas are used, even though the type of flooring desired may be identical. Some are patented and others are, in a way, secret. A general idea of the more common resilient type flooring mixtures is expressed by the formulas given below :

Ingredients.	Bottom coat.	Top coat.	Ingredients.	Bottom coat.	Top coat.
	Per cent by weight.	Per cent by weight.		Per cent by weight.	Per cent by weight.
Caustic magnesia.....	35.0	45	Wood flour.....		10
Sand.....	7.5		Asbestos fiber.....		5
Ground silica.....	25.0	20	Clay, talc, or Sil-o-cel.....	7.5	10
Sawdust.....	25.0		Pigment.....		10

It should be understood that these formulæ are not to be followed exactly for general use. The quality of the magnesite, the physical properties of the inert materials, and the type of floor desired will make modifications necessary in order to obtain the best results. A great deal of experience and some testing of the ingredients is a prerequisite to the proportioning of flooring mixtures.

The ground silica or other fine inert material serves to dilute the magnesia, which to a degree is essential in guarding against large changes in volume typical of the oxychloride cement if used alone. The fibrous materials, especially sawdust and wood flour, and probably Sil-o-cel, produce resiliency; clay and talc act as

diluents but are used chiefly to make troweling easier and to add to the smoothness of the surface. Asbestos fibers also add to the working qualities of the wet mixture.

The dry ingredients should be thoroughly mixed and when ready to use should be made plastic with a solution of magnesium chloride (22° B.). The mixture may then be placed in much the same manner as Portland cement floors are laid. The floor is given a final troweling after it has stiffened considerably but before it has become nonplastic. This operation produces a more compact and smooth surface, making it more resistant to wear and more suitable for polishing or waxing. One without experience should not attempt the laying of composition flooring unless personally supervised by an experienced operator.

Composition floors are laid in one or two coats, each usually one-fourth or three-eighths inch in thickness. Often, if two coats are used, as over wood, reinforcing in the form of wire netting or mesh is first fastened to the floor. There is no uniform practice in the use of reinforcing or in the use of the bottom coat.

The desirable qualities of composition flooring, some of which have already been suggested, are as follows:

- (1) Adaptability for covering old floors.
- (2) Variety of colors which may be obtained by the use of various pigments.
- (3) Resiliency.
- (4) Sanitary advantages owing to the absence of a large number of cracks or joints, and low absorption.
- (5) It is fire resistant. (It can not be considered fireproof as disintegration occurs at moderately low temperatures.)
- (6) It can be laid and is ready for use in a comparatively short time.

2. STUCCO.

The application of caustic magnesia to the exterior stucco trade in this country is of a comparatively recent date. Probably the oldest stucco of this kind was placed 10 or 12 years ago. Although failures with reference to durability occasionally occur, this type of stucco has gained considerable popularity in many localities.

It has a number of features which are very attractive. Owing to the low freezing point of the magnesium chloride solution which is used for wetting the dry mixture, it can be placed during cold weather with very little if any danger of freezing. There is not the tendency to craze or form map cracks upon setting as in

Portland cement stucco. On account of the very low amount of cementing material used in the stucco mixture and consequently the great amount of inert material, this type of stucco seems to show very slight volume changes produced by humidity changes in the atmosphere and by the process of setting. This is one of the reasons for the small amount of cracking usually noted and the absence of crazing. The tensile and compressive strength of such lean mixtures is high compared with other types of stuccos which are made of mixtures with higher percentages of cementing materials.

Caustic magnesia stucco usually consists of two coats, scratch and finish. If a dash is used it is embedded in the finish coat by throwing against the soft mixture on the wall with the hand or a paddle. White sand is generally used in the finish coat for the sake of appearance.

Below is an example of a finish coat for stucco:

	Per cent by weight.
Caustic magnesia.	15
Asbestos fiber.	3
Ground silica.	15
Sand.	67

The under coat might contain less magnesia and some cork. As in flooring compositions an ordinary colored sand could be used. The best results may be had by intelligently modifying the above proportions according to the properties of the plastic magnesia and inert materials.

The dry mixtures are gaged with a magnesium chloride solution (22° B.) to a good workable consistency and applied to the wall with a trowel. The scratch coat should be used to even the surface and cover the high places to a depth of about one-fourth inch. As soon as this has hardened sufficiently to support the finish coat without sagging, or at anytime thereafter, the finish coat is applied to a depth of about one-fourth inch.

If the surface to be covered is dry, it is customary to wet this with the magnesium chloride solution or a thin mixture of caustic magnesia and magnesium chloride just previous to the application of the stucco coat to prevent excessive absorption of the solution from the mixture.

3. SHIP DECKING.

Another important product of caustic magnesia is deck covering for ships. The practice in this trade is very different from that in the flooring trade owing to the peculiar requirement which the

product should fulfill. In covering steel decks, it is necessary to lay the mixture 3 or 4 inches thick in order to produce a plane surface over irregularities such as laps or straps at the joints. It is obvious that this material should be as light as possible, and to effect this quality, it is customary to use as much light weight aggregate as the other requirements will allow. Coarse sawdust answers very well as the bulky part of the mixture, as a finished surface is not often required. Some kind of a covering, such as carpet or tile is usually placed entirely over the composition decking. Of course a finished surface, if desired, may be obtained by coating the decking with a magnesia flooring mixture.

As the composition decking does not bond itself very firmly to the steel plates, it is necessary to use some form of anchorage. One method is to weld a steel strap that has been bent into the shape of a section of Z bar to the steel deck at regular intervals. As a means of preventing corrosion of the steel, it is often coated with bituminous paint.

VI. SPECIFICATIONS.

Until recently no attempt has been made to develop standard tests or requirements for caustic magnesia. Certain purchasers specified that shipments must meet certain requirements, as a minimum and maximum for the carbon dioxide and a maximum for lime, but the limits stated varied considerably. Furthermore, no physical requirements of any kind were ever used, chemical requirements based upon a partial or complete chemical analysis being the sole means used in determining the usability of purchases. As a result of the lack of such physical requirements as minimum strength, low coefficient of expansion, fine grinding, and accelerated aging tests, a variable product was placed upon the market and improperly used. This, combined with lack of knowledge of the quality of the aggregates at hand and improper workmanship, caused certain unsatisfactory results.

With the shutting off of importations during the late war, the calciners in this country were gradually forced to a study of their products, while at the same time the users began to study and test the domestic product which seemed to give results different from the previously used imported oxide. The consequence has been a greater development in a few years of a knowledge of the qualities which a caustic magnesia should have than had taken place since it was first produced as a cementing agent.

A committee representing an organization of producers on the Pacific coast, of manufacturers of caustic magnesia products throughout the United States, of one of the larger domestic producers of magnesium chloride, and two of the Federal bureaus has been engaged lately in preparing a set of specifications and methods of tests for these products.

The chemical analyses or any chemical requirements have been entirely omitted on account of their total inadequacy in defining a satisfactory magnesia. The physical requirements are based upon color, fineness, set, transverse and possibly tensile strength, and linear change in volume. Definite values for these have not been finally determined upon, although the methods of tests have been practically decided upon.

A great deal of discussion has arisen over the desirability of a color standard. As a general rule, the imported product will have a whiter color than the domestic, and consequently the user, on account of his longer acquaintance with the imported oxide, is inclined to prefer white to a slightly tinted magnesia, notwithstanding the fact that in setting and aging the latter will bleach to as white a tint as the former. A suggested compromise has been the requirement that the delivery shall match or be lighter than the one of a series of color standards indicated in the purchase proposal.

Fineness has been a matter to which but little attention has been paid in purchases up to the present. As, however, the speed and the degree of the reaction between the oxide and the chloride depends so much upon this factor, a rather fine product as measured by previous deliveries is desired. Hence a residue of 3 per cent on a No. 100 sieve and 25 per cent on a No. 200 sieve is thought to give a superior product, and at the same time it is a requirement which will not inflict a too great hardship on the manufacturer.

While a very rapid set may give a product of low strength or one with a high early strength but little or no gain in strength with age, and a very slow set a product of low strength, in itself the time of set is more of a matter of ease and economy in usage. Hence neither the initial nor the final set should be so rapid as to entail undue speed upon workmen nor the final set so slow as to make final troweling and finishing a matter of uncertainty or inconvenience. Hence an initial set of not less than one hour and a final set of eight hours is suggested. Both determinations are to be made with the Gilmore needles and upon a mortar

composed of the magnesite in question, fine silica, and standard sand.

The use of such a mortar instead of neat cement for all test purposes has been found to be essential. The results of testing the cement in the neat state are in no way indicative of what will be obtained in practice when the magnesia is used in the form of a rather lean mortar. The suggested proportions for the test mortar are 1 part magnesia, 2 parts fine silica, and 5 parts standard Ottawa sand by weight. The fine silica is white sand or quartz, ground so that 95 per cent will pass a No. 100 sieve and .75 to 85 per cent pass a No. 200 sieve.

In view of the fact that caustic magnesia is used in mortar applied in thin coats and subjected mostly to flexural stresses, it was felt that a strength test should be confined to the determination of the modulus of rupture (transverse strength) of a bar of a cross section of $\frac{1}{2}$ by 2 inches. The suggested bars should be of such a length as to give a distance between supports of 10 or 20 inches. As a suitable machine for such tests is not in common use or on the market, the tensile strength of a briquette of the form used in testing Portland cement has also been suggested. In either case the test specimens are to be broken at the end of 24 hours, and seven days after storage in the air of the laboratory. A good caustic magnesia when so tested will give a transverse strength of 500 pounds per square inch and 1,000 pounds per square inch and a tensile strength of 250 pounds per square inch and 350 pounds per square inch at the end of 24 hours and seven days, respectively.

One of the most common causes of the failure of caustic magnesia cement products is due to the excessive contraction or expansion of the cement; hence the necessity of a requirement in a specification limiting these changes. It has been suggested that the linear change in volume of the bars for transverse tests to be broken at seven days be determined by a suitable micrometer or gage (as the Berry or Olsen strain gage) at final set, 24 hours and seven days after final set. With proper reference points and an optical bench the measurements may be started immediately after placing the reference points. The suggested limits of a contraction not to exceed 0.15 per cent or an expansion not to exceed 0.30 per cent of the original length may seem to be excessive. However, the mortars are always used in thin layers upon a base which is stable so far as volume changes are concerned and which acts as a reinforcing. In certain cases,

as in flooring on old wooden floors, reinforcing is actually used. Consequently the volume change in practice is not nearly as marked as that obtained in the test specimen. In some work at the bureau involving tests of samples of commercial composition flooring the linear change in volume was measured on bars of the flooring of the type indicated above and on bars of the flooring laid upon a bar of aged Portland cement mortar, such as might be used to cover concrete slabs and in turn be covered with composition flooring. Simultaneous observations made on the two sets of bars show that the volume change in the latter type of bar will be but from 10 to 30 per cent of that of the former type.

The above indicates the factors which are being considered in the preparation of specifications and also that might be used in the meantime as tests by those wishing to secure some idea of the quality of caustic magnesia in which they are interested.

WASHINGTON, July 25, 1922.

